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A PILOT PLANT FOR SOLVENT EXTRACTION STUDIES[1]

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In the solvent extraction of soybeans, usually eight different operations take place. These can be considered in two groups--soybean preparation and soybean extraction. We are investigating all of the individual operations to find the factors that affect the economy of operation and the quality of products.

Of course, the solvent extraction of soybeans is being conducted successfully on a commercial scale every day. But somewhere among the operational steps lies a vast opportunity to improve the products. Until this is accomplished, soybeans can hardly be expected to reach their full utilization industrially. And upon this hinges, in large measure, the future of the crop from both an agronomic and an industrial standpoint.

Our equipment is designed to process soybeans by a continuous operation at the rate of 40 pounds an hour. Although this capacity is small, yet practically all the problems encountered in commercial units are present in our pilot plant, and its design is such that operating conditions can be changed readily and research data taken on almost all operations.

As an example of the versatility of this pilot plant I might mention work on the use of various solvents. Practically all solvent-extraction plants in this country use commercial hexane as a solvent. One phase of our research is the investigation of other solvents. Hexane is used because of its low cost and its efficiency. Ethyl alcohol, when used as a solvent, removes many nonoil constituents which may be valuable, and also produces a meal that is more suitable for the preparation of industrial and edible protein. Trichlorethylene is a nonflammable solvent, and for that reason will be included among our studies.

The efficiency of the steps which make up the total of the extraction operations depends to a great extent upon the quality and condition of the flakes. Therefore, let us start with preparation of the flakes, the first step, and follow them through successive operations in regular order.

First, the beans are cleaned of foreign material and elevated to the storage bin of the pilot plant. This bin has a capacity of 15 bushels and its location, together with equipment used throughout the flaking process, is indicated on the accompanying flowsheet, Figure 1. From this operating bin, the beans move to the cracking rolls through a variable-speed screw conveyor, the speed of which can be regulated to give the desired feed rate. The beans are cracked in a set of corrugated rolls 12 inches in diameter, which turn with differential speeds. These rolls crack the beans to particles ranging in size from eighths to quarters. It is highly desirable to produce uniformly cracked particles with a minimum of fines.

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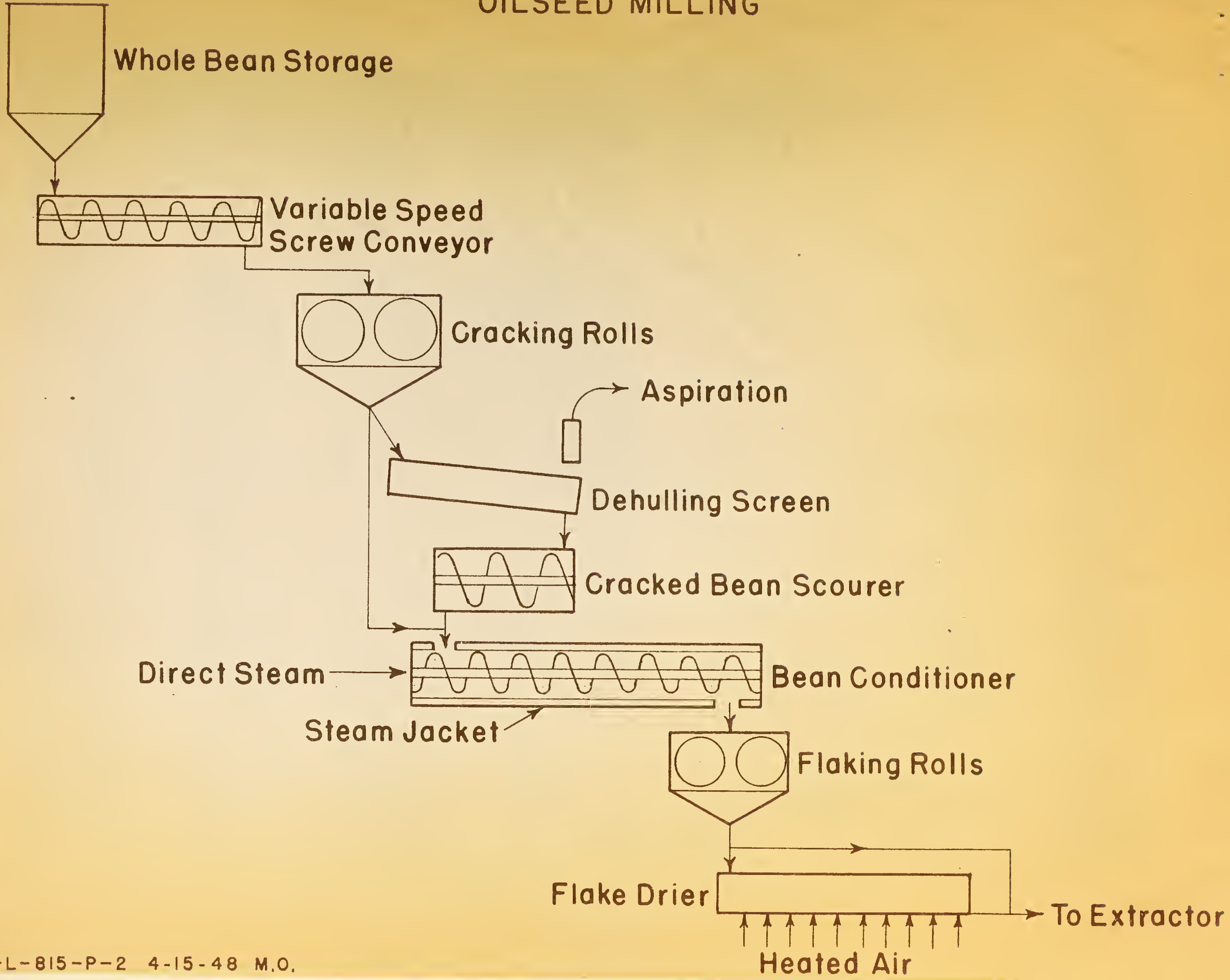
The cracked beans are then conveyed to the dehulling equipment. This consists of a shaker screen with air aspiration to remove loose hulls, and a scourer which agitates the beans to remove the hulls which did not break free previously. The dehulling equipment is used only when we wish to produce an extracted meal which is suitable for edible use or for a special purpose. Normally, dehulling is bypassed and the cracked beans are conveyed directly to the tempering apparatus.

The temperer is a screw conveyor provided with a steam jacket, with provision for adding steam directly for moistening the beans. This equipment heats and adjusts the moisture content of the cracked beans, as required, in order to produce good flakes. In commercial practice, the procedure for flaking the beans varies among plants and the amount of moisture desired and the temperature to which the beans are heated depend on the type of flaking rolls in use and the condition of the whole beans. Processors strive for flakes that are thin but uniform in thickness, not easily broken, and which have a certain bulk density. Usually, no two plants operate their tempering equipment in the same way. Very little information has been published concerning the best conditions for tempering the beans to produce the proper type of flakes. It may be that certain temperatures and moisture contents will be more beneficial than others.

In our solvent-extraction pilot plant, the beans are heated to about 170°F. and the moisture content is adjusted to about 10 percent. The flakes are prepared by a set of smooth rolls 12 inches in diameter. These flakes are about the size of your thumbnail and 0.008 inch thick. Their uniformity of thickness is highly desirable for regularity in the extraction process. They are made as thin as is practicable, however, since this reduces the time required to extract the last of the oil. In our experience, we have found that more than 90 percent of the oil can be removed within the first few minutes, but the extraction of the remainder requires as much as an hour's retention time. The amount of fines and the friability of the flakes are important factors which affect the flow of the solvent. A certain amount of fines is desirable to retard the solvent in its flow through the flakes, but an excess of fines causes the solvent to seek the path of least resistance so that channeling occurs, with a resultant drop in extraction efficiency.

In these small flaking rolls, the problem of producing good flakes is always present and many of the troubles we have do not occur in commercial plants which use rolls as large as 4 feet in diameter. The size of the flaking

OILSEED MILLING



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rolls is important. Large rolls nip the cracked beans readily, and produce uniform flakes. As the size of the rolls is diminished, their ability to nip the beans also decreases. Consequently, at high feed rates, material accumulates on top of the rolls. This trouble is aggravated if the beans are not tempered properly.

The flaked beans may be dried when alcohol is used as a solvent or, when hexane is employed, they may be sent directly to the extractor. If the flakes contain 3 percent or less of moisture, the alcohol will not dissolve any of the water and the solvent may even be partially dehydrated. The drier we use is one of our own design and construction. It took some time and effort to find the best way of drying the flakes without causing any overheating or excessive breakage. The drier we made is essentially an endless screen belt which supports the flakes while heated air passes up through the screen and flake bed. The versatility of our research equipment is well illustrated by this flake drier. A flake bed of variable thicknesses can be spread on the belt, any retention time from 3 to 15 minutes may be selected, the amount of heated air passing through the flake bed can be adjusted, and the temperature of the heated air can be controlled. If it should be desirable, it would even be possible to dry the flakes in an inert atmosphere. In addition, all of the parts are simple in construction and accessible for adjustment.

The milling equipment where our beans are prepared for extraction includes the bean storage hopper, the variable-speed feeder conveyor, the cracking rolls, the dehulling equipment, the temperer, and the flaking rolls. The various pieces of equipment are connected by bucket-type elevators and screw conveyors to provide for continuous flow of the material. These elevators and conveyors are located back of the equipment. The arrangement would have been much simpler if we could have located the units so as to use gravity flow from one operation to the next.

One of the biggest problems in solvent extraction is material flow. Soybeans which are flaked and moist are capable of forming very solid plugs in conveyors, rotary valves, and even in the larger pieces of equipment. All conveyors and elevators should be made as self-cleaning as possible. If wet beans or flakes are allowed to accumulate in a piece of equipment, their decomposition will produce a very obnoxious odor and, of course, the decayed matter will contaminate the products.

The two processes of milling and extraction are carried out separately in different rooms with special ventilation for each. All of the electrical equipment for the milling room is dust-tight and conforms to the Underwriters' Laboratories' Code for Class II Group G locations. The electrical controls and motors used in the extraction room are of explosion-proof construction.

Figure 2 is the flowsheet for the extraction plant. The Kennedy-type extractor in which the flakes are processed is about 25 feet long and 10 inches wide. It has 20 stages or sections, each one of which consists of a trough and a paddlewheel. The wheels rotate very slowly at a rate of approximately one revolution every 5 minutes. The flakes are pushed very gently through the solvent from one stage to the next. Each section is provided with an outlet through which samples of the miscella can be withdrawn. The miscella is a solution of the solvent and the oil. The extractor is placed on a slight slope so that the solvent which is introduced at one end flows by gravity, countercurrent to the flakes, to the other end of the extractor. The flakes are fed into the extractor by a screw conveyor, the speed of which can be varied. The drive for the paddlewheels can be adjusted to give any desired retention time ranging from 15 minutes to 2 hours. The temperature of the process can be controlled by regulating the temperature of the water in a jacket beneath the extractor. The flow rate of the solvent to the extractor is measured by a rotameter. The solvent is preheated by a small steam heater. The usual retention time for soybean flakes having a thickness of 0.010 inch is 1 hour, and a ratio of 1.25 or 1.0 pound of solvent per pound of flakes is employed. This should give a meal having a residual oil content of 0.8 percent. With only slight deviations, these conditions are typical of the operations in commercial plants.

Of course it is desirable that the ratio of solvent to beans be as low as possible without detracting from the efficiency of the extraction. With lower ratios there is less solvent to be removed from the oil in the evaporation step and consequently less steam is required.

After the flakes pass through the last section of the extractor, they are elevated by a drag-link conveyor which allows the excess solvent to drain away. They enter the flake desolventizer through a rotary valve which acts as a vapor seal. At this point the extracted residue contains approximately 30 percent of moisture and volatile matter. The drier is designed to remove the solvent from the flakes without overheating them. Removal of the solvent at low temperatures is desirable when the protein in the meal is to be utilized for some special purpose other than for feeds. The construction of the desolventizer is somewhat similar to a French stack cooker, with which some of you may be familiar. Our unit consists of four steam-heated shelves placed one above the other. A revolving scraper moves the material across a shelf until it falls through an annular hole to the shelf beneath. The desolventized meal is removed by a screw conveyor and passes through another valve which serves as a vapor seal. These valves are constructed with spring-loaded vanes to provide for taking up the wear. Steam is not used to strip the last traces of the solvent from the meal because of the difficulty encountered when steam condenses and causes the meal to form a solid plug. However, we have been able to obtain solvent-free meal without the use of stripping steam, as is practiced in commercial operations.

The vapors from the meal drier are filtered to remove any dust which may foul the condenser tubes and which also helps to form an emulsion in the water-solvent separator. The dust filter is steam-jacketed to prevent condensation of solvent vapors as they are filtered through a layer of flannel cloth. The vapors are then condensed in an ordinary tube-and-shell condenser. The liquid and any non-condensable gases are removed by a wet-type vacuum pump and the liquid enters a solvent-water separator before the solvent is returned to the storage tanks.

The miscella coming from the extractor is collected in storage tanks, then filtered in a plate-and-frame filter press. The filtered solution is pumped to overhead tanks, and feeds by gravity to the solvent removal system. The solvent is removed from the oil in two steps. The major portion is recovered in an evaporator of the natural recirculation type and the remainder of the solvent is separated from the oil in a stripping column. The flow rate of the miscella to the evaporator is measured by a rotameter. The evaporator consists of a vertical steam-jacketed tube bundle with seven 3/4-inch tubes 5 feet long. This unit is intended to operate with steam at low pressures of 2 to 5 p.s.i. gauge or under a low vacuum, if desired. Regulators are provided for controlling the vacuum in both the evaporator and the stripping column.

The oil solution, which should be concentrated to 90 percent, is withdrawn from the evaporator, through a rotameter, and into the stripping column by the higher vacuum in the latter unit. This stripping column is made up of seven 1-inch tubes, 8 feet long, jacketed with low-pressure steam and provided with a distributor for the film of oil that should flow down inside each of the tubes. At the bottom of the tube section the oil passes through a section of 1/2-inch Raschig ring packing 18 inches deep. Beneath this packed section and above the oil receiver dry stripping steam is admitted to remove the last traces of solvent. The column is operated under vacuum and the solvent vapors from both the evaporator and the stripping column are combined and condensed in a common condenser. The condensate is handled by the vacuum pump and solvent-water separator mentioned previously. The crude oil from the stripping column passes through a cooler on its way to the storage tanks. This completes the operations that take place in our solvent extraction plant.

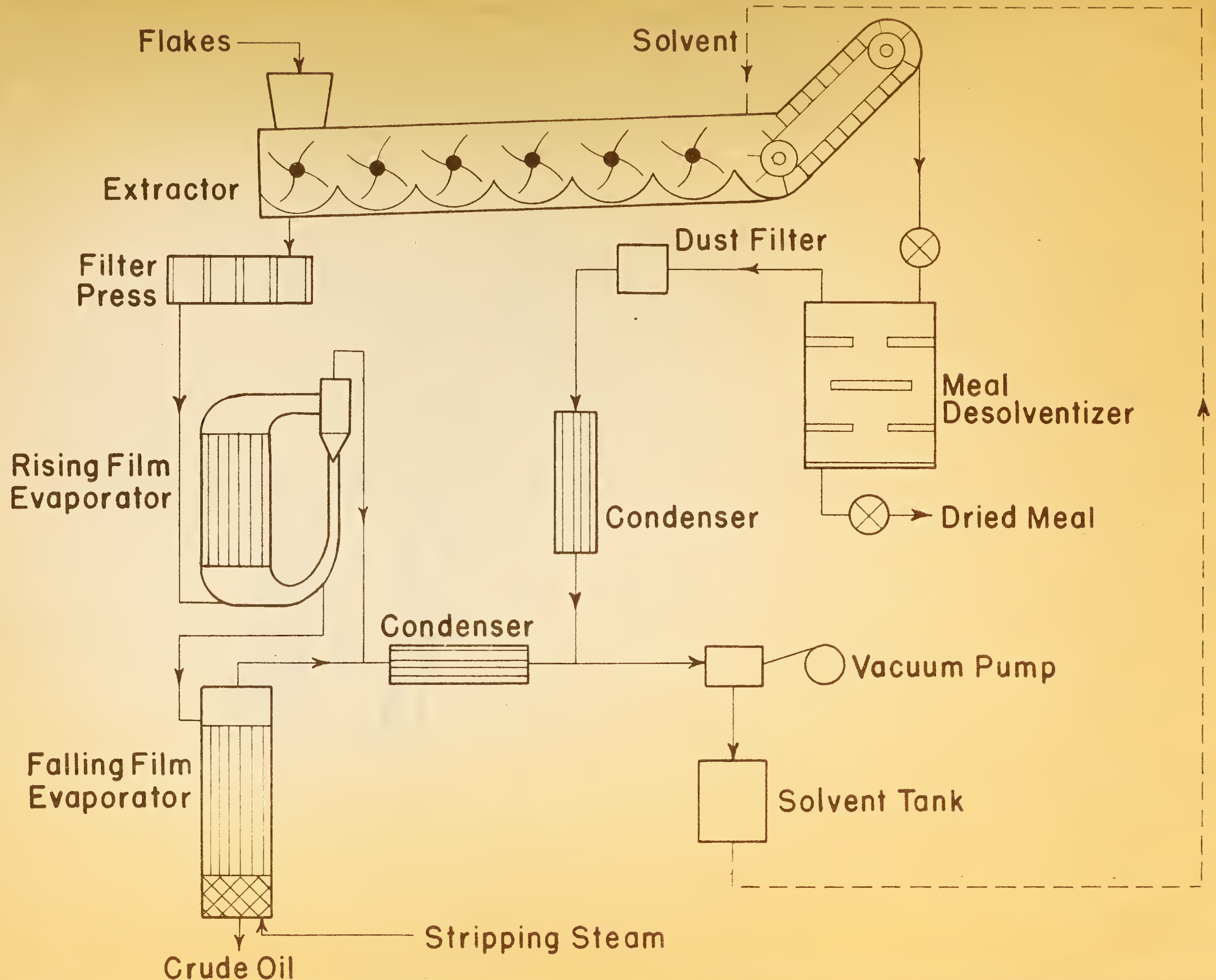
In conclusion, I should like to mention more about the studies on soybean processing which are planned at this Laboratory. Within a short time, we shall be working on a project in cooperation with soybean processors to determine the solvent extraction conditions which will produce the best meal for animal feeds. Several factors will be investigated. The first experiments will be concerned with the variables in the cooking operation, and later different varieties of beans may be studied, as well as the effects of the extraction operation itself. The meal is to be evaluated by feeding tests which will be conducted by the processors cooperating in this research. Another problem to be undertaken is that of extracting the oil from new varieties of soybeans for comparison with that obtained from the usual varieties.

Some studies have been made at this Laboratory on the flavor stability of soybean oil as it is affected by the treatment the oil undergoes during removal of the solvent. We expect to make further investigations to determine the types of equipment best suited for treatment of the miscella.

From time to time we shall do special work for other Divisions of the Laboratory. Samples of oil and meal of known history will be prepared for the research chemists.

Although soybean research is the primary problem of our group, we expect also to work with other oilseeds such as flaxseed and sunflower.

OILSEED EXTRACTION



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